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VARIATIONS IN MANUFACTURING PROCESSES 155 MM COMBUSTIBLE CARTRIDGE CASE

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20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

The work covered by this report consisted of the manufacture of molded 155 mm combustible casings, 30 inch (76.2 cm) P/N 9342960 with three different resins (30 each with Marbon 1600, Dow Latex 241, and Duralok); an investigation of the spiral wrapping parameters of manufacture of 155 mm combustible cartridge case, 30 inch (76.2 cm); evaluation of two candidate adhesives used in spiral wrapping; and manufacture of 25 cases by spiral wrapping with each candidate adhesive.

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INTRODUCTION

This contract was awarded by the Department of the Army, U.S. Army Armament Research and Development Command, as part of an ongoing effort to get improved physical and combustion properties in 155MM combustible casings and improved manufacturing methods. The contract, DAAK10-82-C-0013, with its subsequent modifications, required the investigation into and manufacture of a number of combustible casings by the molding process and by the spiral wrapping process. The parameters of these processes were previously investigated under contract DAAK10-80-C-0172. The use of three different resins in the felting formulation for molded cases was evaluated, and the use of two different adhesives used in case manufacturing by spiral wrapping was investigated. Specific data was also recorded on the manufacturing processes and tests performed to evaluate the manufactured products.

PLAN OF INVESTIGATION

The contract scope of work originally consisted of four tasks, modified by change P0002 to three tasks as outlined below.

Task one called for the delivery to the government of 90 molded 155MM combustible cases, 30 inches long (76.20 cm) in three lots of thirty each. Each lot was to be molded at the Armtec, Coachella, CA plant utilizing a felting slurry with a 13% resin content made from one of three test materials. These were Marbon 1600, a styrene butadiene resin, Duralok, a modified polyvinylacetate, and DOW Latex 241, a styrene butadiene resin. The three resins were investigated as agents for binding fibers in the molded cases. The density and ultimate tensile strength (UTS) of molded cases was to be determined by Armtec. The combustibility of cases was to be determined by the Army from the molded cases shipped to ARRADCOM for evaluation.

Task three (task two was eliminated) called for the evaluation by Armtec of the parameters of the manufacture of 155MM cases by the spiral wrapping process as used in the commercial production of fiber products. Information gained in this task was to be used during manufacture of parts in task four. Items to be evaluated were feed paper width, thickness, and speed, paper tension, winding speed, the trimming of finished parts, and number of feed rolls required.

Task four called for the evaluation of two candidate adhesives to be used in binding plies in the cases manufactured by the spiral wrapping process. They were Rhoplex N495 and Rhoplex LC45, both made by Rohm and Haas. Twenty-five 155MM cases were to be manufactured by the spiral wrapping process using each of the two candidate adhesives for a total of fifty cases. Evaluation of the following was required: drying time, wettack, combustibility and strength of wrappings.

PROCESS OF MANUFACTURE

Process Description - Molding

The current state-of-the-art for the molding of high density consumable ordnance items evolved from various slurry preform and pressing techniques that were employed during the past century in the manufacture of three dimensional shapes from wood cellulose fibers. Basically it is a commercial art for making hollow wares of a paperboard-type composition.

The present, controlled concept employed by Armtec in making high-density, combustible ordnance items is described in the following sections. The method described was employed to manufacture the detail parts applicable to this report (fig. 1).

Batch Preparation

1. A hydropulper is filled with a predetermined amount of water.

2. A specific amount of Kraft fibers is added to the water.

3. The mixture is beaten until the desired freeness is attained.

4. A measured amount of nitrocellulose fibers is then added.

5. The entire batch is agitated until a homogeneous mix is obtained.

6. The homogeneous mixture is pumped to the mixing tank.

7. Resin is added within the mixing tank by employing the various prescribed steps that will obtain complete precipitation of the resin upon the fibers. Also, nitrocellulose stabilizer, DPA, is added.

8. The batch is then pumped to a large storage tank, and sufficient water is added to reduce the slurry consistency to approximately 0.15% solids.

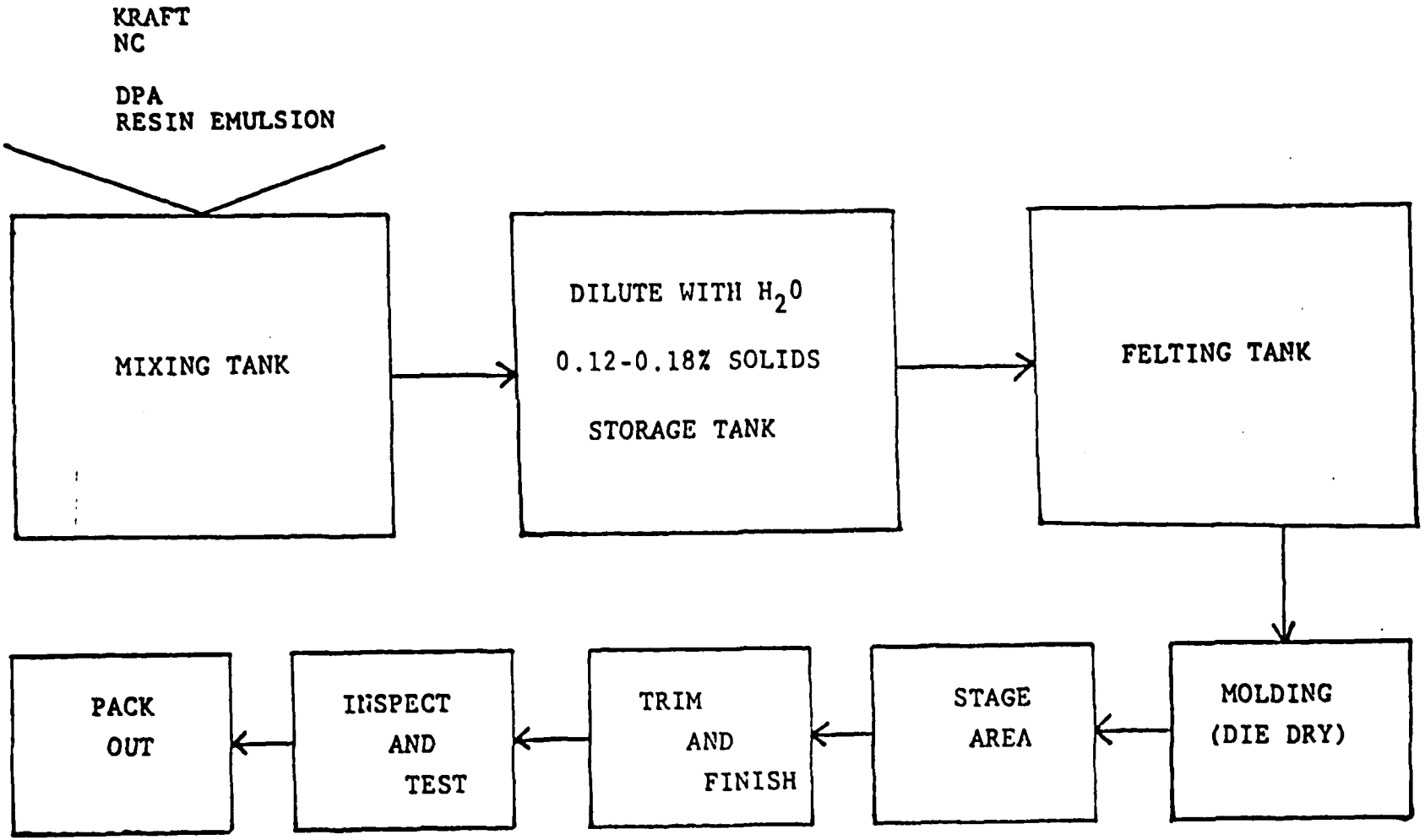

Figure 1. Schematic of molded consumable case production process

9. The batch is then allowed to stand under constant agitation for a minimum of one hour.

10. The slurry is pumped from the supply tank to the felting tank on a continuous basis. The slurry mixture is kept in constant agitation by mechanical methods.

Felting

The felting tank is rectangular. The slurry input is from the bottom center with a rectangular baffle, mounted to give a 1/4-inch opening or slot between the baffle and the tank bottom, thus diffusing an equal amount of slurry in all directions. The felting tank is allowed to overflow equally over a weir and into a return trough on all four sides. This is designed to give the best possible distribution of the slurry mixture within the felting tank.

Preforms are made in the felting tank by vacuum accretion of the fibers onto a perforated and screened shaped (felting die) having exterior dimensions comparable to the configuration of the desired shape. The perforated shape is affixed to a manifold which is connected to a vacuum source.

The felting die is immersed in the felting tank, and a vacuum is applied. The length of immersion time plus the rate of the vacuum source dictates the amount of build up of fibers around the exterior wall of the preform die. This, in turn, controls the weight of the preform.

When the preform, or felt, is removed from the felting die, it is a soggy, loosely woven matrix (approximately 60% water) with a wall thickness approximately 3 1/2 times greater than the finished part to be molded.

Molding

The wet felt is dewatered and cured by a predetermined molding cycle in the steam-heated (350°F) matched metal dies. The male section of the die contains vertical grooves closely spaced on the die face. These grooves are connected to a manifold at the base of the male die. The manifold is connected to the vacuum source.

Dewatering is effected in two steps. First, the free water is literally squeezed out through the vacuum grooves during the die-closing operation. The remaining moisture is then vaporized by the die heat and is vented through the vacuum grooves.

The resin is cured at the elevated temperature during the closed-die cycle (which is approximately 3 1/2 minutes). The dried part is ejected from the male face by compressed air via the vacuum manifold and grooves.

Spiral Wrapping

Standard commercial papermaking equipment is used to manufacture nitrocellulose paper rolls of the required formula. The rolls of nitrocellulose paper are placed on a commercial spiral core-winding machine which is capable of producing tubing in a variety of diameters, lengths, and laminates. This process makes only the case sidewall. The detail parts (end caps, igniter caps, forward cap and glue ring) can then be produced by conventional fiber molding.

PERFORMANCE OF INVESTIGATIONS

Task 1

The formulation for the molded 155MM cases (P/N 9342960) is given below. The three test resins were alternated in the batch formulations (table 1). The Duralok resin batch 039 was made without talc and was used to mold all detail parts (igniter cup and end cap) for the cases irrespective of the resin used in the case batch.

FORMULATION
(slurry for molded cases only)

Nitrocellulose (NC)(12.6%N)	51.10%
Kraft	25.5%
Resin (Marbon 1600, Duralok, or Dow 241)	13.0%
Talc	9.5%
Diphenylamine (DPA)	1.0%

Thirty cases from each batch containing one of the three resins were made in March, 1982. Tests of the density, ultimate tensile strength, and stability were made on parts molded from each batch. Results are given in table 2.

The required combustibility test was to be performed by ARRADCOM.

Finished parts, 30 cases each from batches 038, 040, and 043 were accepted by the government and shipped to the ARRADCOM Support Activity, Dover, NJ on 16 November 1982.

The performance of the three resins under test proved similar in firing tests performed by ARRADCOM. The Duralok resin produced least residue. Marbon produced more than Duralok, and Dow 241 produced the most residue of the three.

Table 1. Chemical analysis of molded 155MM cases

Batch no.:	038	039	040	043
Resin system percent	Marbon 1600	Duralok	Dow 241	Duralok
DPA	0.64/ 0.60	1.27/ 1.19	1.05/ 1.02	0.84/ 0.81
NC	53.86/53.91	72.81/73.34	52.98/53.05	54.86/54.90
KRAD	45.50/45.49	25.92/25.47	45.97/45.93	44.33/44.26
Talc - Top	6.36	0	7.47	7.38
Talc - Middle	6.43	0	7.55	7.34
Talc - Bottom	6.37	0	7.72	7.32
Talc - Average	6.39	0	7.58	7.35

Table 2. Density, tensile strength and stability 155MM molded cases

Batch no.:	038	039	040	043
Resin system	Marbon 1600	Duralok (no talc)	Dow 241	Duralok (with talc)
Density g/cc				
Top	0.933	0.972/0.980	0.944	0.97
Middle	0.958	----------	0.957	0.99
Bottom	0.933	----------	0.994	1.01
Average	0.941	0.976	0.965	0.99
Ultimate tensile strength psi				
Top	2818	4225/4437	2711	3524
Middle	3255	---------	3245	3302
Bottom	3407	------ --	3061	3909
Average	3160	4331	3006	3578
Stability	OK	OK	OK	OK

Task 2

Task 2 was deleted from the original Scope of Work by Modification P00002 on 25 June 1982.

Task 3

This task was an evaluation of the parameters of the spiral wrapping method of manufacturing 155MM combustible cases. It followed and enlarged upon previous work done to investigate this method, determine its requirements, develop materials and techniques, and evaluate manufactured products.

There were two areas of investigation in this task: the manufacture of nitrocellulose paper, and the wrapping of that paper into 155MM cases of the required dimensions. Final trimming of cases was done at the Armtec plant, Coachella, Ca.

The nitrocellulose paper was manufactured in February 1982 at the Herty Foundation, Savannah, GA under their project 2114, utilizing a Fourdinier (paper felting) machine.

Three rolls of nitrocellulose paper (approximately 180 lbs. each) were made using the following formulation:

Nitrocellulose	65%
Kraft fiber	10%
Kurlon fiber	3%
Talc	10%
Marbon Latex 1600	12%
Diphenylamine	1%
Kymene	0.2% added
Aquapel	0.2% added

The following steps were performed to prepare the paper furnish:

1. The nitrocellulose and the refined Kraft (472 CS Freeness) were added to a 3500-gallon chest.

2. The pH of the slurry was adjusted to 9.0 with Na_2CO_3.

3. The Marbon resin was diluted to 20% solids prior to premixing with the talc.

4. The resin-talc solution was then added to the furnish.

5. The pH of the furnish was lowered to 4.3 with alum.

6. The DPA (pre-dissolved in 40 liters of Methanol) was added below the surface of the furnish.

7. Added 0.2% Kymene 557 H

8. Added 0.2% Aquapel

Stock was pumped from the machine chest and metered with a Foxboro Flow Controller to the suction of the fan pump where white water from the wire was added to give the required paper-making consistency. Diluted furnish was pumped with the fan pump through a five-pipe manifold into the headbox.

A successful effort was made to calender paper "on the fly" as it came directly off the Fourdinier machine.

Papermaking data is shown in table 3.

Testing was as follows:

1. Basis weight and Caliper of each roll was determined. Results are shown in table 4.

2. Caliper, Burst & Tensile tests were run on samples of paper made in run 1991 and run 2114. Results are shown in table 4.

Table 3. Paper machine data, run 2114

Run number	2114-1
Chest Freeness, C.S., ml.	526
Consistency, percent	4.5
pH	4.2
Headbox freeness, C.S., ml	519
Consistency, percent	0.84
pH	4.3
Homogenizing Roll, r.p.m. Top	150
Shake, strokes per minute	150
Slice opening, inches	up
Machine speed, f.p.m.	50
Vacuum in Hg. 1st box	4.5
2nd box	3.0
3rd box	3.0
4th box	2.5
couch	4.5
Pressing PLI, 1st press	180
2nd press	170
Pressing PLI, calender	530
Drier pressure psig	
1st section, drier no. 1	0
no. 2	0
no. 3, 4	0
no. 5, 6, 7	8
2nd section, drier no. 8, 10, 12	20
no. 9, 11	20
Ream (24"x36"-500) lbs.	183
Date of Run, 1982	3-3

Table 4. Nitrocellulose paper physical test data

Roll number	Weight lbs/3000ft^2	Caliper mils			Burst lbs/in.	Tensile lbs./in.	
		Front	Middle	Back		MD(1)	CD(2)
2114-1	Test only						
2114-2	180	19.1	18.7	17.5	14.1	12.7	8.5
2114-3	190	19.0	18.3	17.3			
1991-1 (Before) (Calender)		23.2	23.5	23.5			
1991-1 (After) (Calender)		17.5	17.4	17.5			
1991-2 (Before) (Calender)	192	24.0	23.2	23.2	23.2		
1991-2 (After) (Calender)	192	18.2	18.0	18.0	40.7	37.5	19.4

(1) Machine direction
(2) Cross direction

Table 5. Paper machine data, run 1991

Run number	1991
Chest Freeness, C.S., ml.	546
Consistency, percent	4.45
pH	4.40
Headbox Freeness, C.S., ml.	540
Consistency, percent	0.82
Homogenizing roll, r.p.m.	90
Top	100
Shake, strokes per minute	150
Slice, opening, inches	up
Machine speed, f.p.m.	50
Vacuum in Hg. 1st box	4.0
2nd box	3.0
3rd box	3.0
4th box	2.5
couch	4.0
Pressing PLI, 1st press	180
2nd press	170
Drier pressure, psig	
1st section, drier no. 1	0
no. 2	8
no. 3, 4	10
no. 5, 6, 7	10
2nd section, drier	
no. 8, 10, 12	16
no. 9, 11	18
Date of run, 1981	4-9

Nitrocellulose paper designated 1991 was made using the following formulation:*

	Percent
Nitrocellulose	55.0±2.0
Kraft Fiber	15.7±1.0
Kurlon	4.3±1.0
Diphenylamine	1.0±0.3
Dow Latex 241	12.8±1.0
Talc	10.0±1.0

Caliper -0.25 in. -0.27 in.

These steps were performed to prepare the proper furnish:

1. Nitrocellulose, Kurlon, Kraft paper and talc were blended in a 7,000 - gallon chest.

2. The latex was added with no pH adjustment

3. Diphenylamine was dissolved in Methanol at 160 grams per liter and metered under the surface of the furnish.

4. Alum was used to adjust the pH of the furnish to 4.4

Raw materials to produce the required nitrocellulose papers were supplied by Armtec to Herty Foundation, along with formulation instructions. The paper for Herty projects 1991 and 2114 were manufactured with standard paper-making equipment.

The papers (1991 and 2114) were calendered as shown on table 4 and forwarded to Sunoco Corp., Hartsville, SC for spiral wrapping of case sidewalls.

The 1991 paper, manufactured in 1981, had Dow Latex 241 as a resin. The 2114 paper, manufactured in 1982, contained the Marbon 1600 resin. These two papers were used in separate manufacturing runs to evaluate their use in the spiral wrapping process.

At Sunoco the paper in rolls was slit to widths of 5 in. and 5 3/8 in. for use on their spiral winding machine, a Sunoco designed and built piece of equipment. Multiple rolls of the slit paper are fed under tension through an adhesive applicator onto a revolving mandrel. The strip material is fed on a bias with each subsequent wrap overlapping the seam of the previous wrap, thus providing the spiral tube configuration. The tubing is automatically forwarded on the mandrel to a cut-off blade where

*Formulation taken as it appears in Herty Foundation Report 1991, 8 April 1981.

it is cut to length. The paper was wound on a mandrel producing a 6-inch diameter tube at winding speeds as seen in table 6. Lineal feet of paper per minute producing a number of tubes per minute and tube tensile strength are also shown in table 6.

The cases were wrapped to 5 plies with a feed roll for each ply.

Paper tension maintained by spring-held fingers in normal papermaking had to be removed due to the lack of strength in the nitrocellulose paper.

The target thickness of nitrocellulose paper during this program was 0.019 in. caliper or less.

The characteristics of the nitrocellulose paper and cases manufactured from the two papers are shown in table 7.

Table 6. Spiral winding speeds

	1991 paper	2114 paper
Paper feed ft/min	27	16
Tube formation Lineal ft/min	7.6	4.5
30" Tubes/min	3.0	1.8
Tensile Kg (F)/m*	870	495

The 1991 paper ran faster due to the higher strength of the material.

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* Kilograms force per meter.

Table 7. Characteristics of nitrocellulose paper

Run	2114	1991
Resin	Marbon 1600	Dow Latex 241
Basis weight	179.7 lbs.	191.6 lbs.
Caliper	17.4 mil	17.5 mil
Mullin burst test	14.1 psi	40.7 psi
Tensile strength:		
machine direction	12.7 psi	37.5 psi
cross direction	8.5 psi	19.4 psi
manufactured case	577 psi	1013 psi with talc
		1572 psi without talc
Density	0.80	0.82 with talc
		0.70 without talc

Either Marbon 1600 or Dow Latex 241 Latex resins are seen to produce adequate parts by the spiral wrapping method. A reasonable number of cases per minute can be manufactured as shown in table 6.

Task 4

This task called for the evaluation of two candidate adhesives for use in binding nitrocellulose paper plies together. They were Rhoplex N495 and Rhoplex LC45, both made by Rohm and Haas.

The paper roll for each ply (except the top one) in the spiral wrapping process winds through a supply roller mechanism which coats the top surface of the paper with the adhesive. This causes adhesion to the next ply laid down on top of it.

Characteristics of the two adhesives tested are shown in table 8.

The two adhesives were used to manufacture forty 155MM combustible cases, (P/N 9344131). Twenty-five cases using Rhoplex LC45 were shipped to ARRADCOM on 10 December 1982 and fifteen using Rhoplex N495 were shipped on 14 January 1983 for combustibility testing and product evaluation.

Table 8. Adhesive characteristics

N495	LC45
Makes up thick, moves slowly, sets up slowly	Makes up thin, moves easily, sets up quickly
Time until tacky: about 30 minutes	Time until tacky: less than 5 minutes (by time case is cut to length)
Dryness measured at 12 hours: still damp	Dryness measured at 12 hours: dry

CONCLUSIONS

The conclusions drawn from the investigations made on this contract are given below for each of the primary tasks.

Task 1 - Molding of 155MM cases using felting formulations each with one of three test resins to promote fiber adhesion.

It was determined that any of the three resins tested, Marbon 1600, Dow Latex 241, and Duralok, would produce a good molded case within the acceptable limits of strength, tolerances, and ease of manufacture. The Marbon 1600 is recommended as foremost of the three resins, primarily because of its successful history of application by the British.

Task 3 - Manufacture of nitrocellulose paper and spiral wrapping of 155MM cases.

There are a number of difficulties in producing nitrocellulose paper and manufacture of cases by spiral wrapping, most of them associated with the inherent lack of strength of the nitrocellulose paper. The speed at which the spiral wrapping can be done is directly related to the paper strength. However, satisfactory production speeds have been attained and can be improved with better paper strength through manufacturing experience.

Task 4 - Evaluation of two Rohm and Haas adhesives, LC45 and N495, for use in gluing plies together in spiral wrapping manufacture of 155MM cases.

The LC45 adhesive was found to be more desirable than the N495 because it has a faster set-up time and less tack as measured after 12 hours. However, either LC45 or N495 are believed to be satisfactory adhesives for the manufacture of cases.

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